ARS-73-9

UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Service

POTATO FLAKES

A NEW FORM OF DEHYDRATED

MASHED POTATOES

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II. SOME FACTORS INFLUENCING TEXTURE

August 1955

POTATO FLAKES, A NEW FORM OF DEHYDRATED MASHED POTATOES
II. SOME FACTORS INFLUENCING TEXTURE

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In an earlier paper (1)[2] we described a process for making a new form of dehydrated mashed potato, now well known as potato flakes. It is produced by dehydrating mashed potatoes on a double drum drier under operating conditions in the range of control easily maintained with such machines. The dehydration is accomplished in a single stage.

Potato flakes have excellent appearance and flavor. Problems of control of these attributes in the flake process are minimized because the potatoes are ready for drying immediately after mashing, and the dehydration is accomplished in less than half a minute after application of mashed potato to the drier drums. Therefore, the development of off-flavors, due to long holding periods or prolonged heating during dehydration, is minimized. A desirable, subtle baked potato flavor is imparted during this short dehydration.

Good appearance and flavor are essential requirements in a mashed potato but they are less difficult to achieve than the important attribute -- good texture. A desirable product is one which has texture as near that of fresh mashed potato as possible. It should be mealy and not pasty or gummy. By avoiding cell rupture and concomitant release of free starch, pastiness can be reduced, but this alone does not achieve good texture. Mashed potato may contain little free starch, but at the same time lack a desirable mealiness. Recent developments in the potato flake process indicate that mealiness of the reconstituted mashed potato depends mainly on the manner in which the potato is treated prior to mashing and dehydrating. The most important single factor controlling mealiness is the recently developed "precooking" step in which the potato is heated, prior to final cooking at 212° F. (100° C.) to a temperature in the range of about 140 to 180° F. (60 to 82° C.) for a

1. A Laboratory of the Eastern Utilization Research Branch, Agricultural Research Service, United States Department of Agriculture.

2. Numbers in parenthesis refer to Literature Cited, Page 8.

suitable time. Through the use of the precooking step it is now possible to make a mealier product not only from high solids content potatoes usually used in dehydration processes, but also from lower solids content potatoes not suitable heretofore. This paper deals primarily with the precooking treatment and reviews briefly the other factors affecting texture previously reported in detail (1).

PILOT PLANT PROCESS

Since the process and machinery used have been described in detail in a previous paper (1), only a brief description is given here. A flow sheet of the potato flake pilot plant is shown in Figure 1. Raw potatoes are abrasion peeled, hand trimmed and sliced into 5/8" thick slices. Slices are washed to remove free starch from the cut surfaces, dipped one minute in sulfite solution, precooked in water or steam, finally cooked in steam at 212° F. (100° C.), and then mashed in an extruder type (Sepra-sieve)[3] mixer. The mashed potato is then sulfited and is diluted with water when desirable, to adjust solids content and to improve adherence to the drums of the drier. This diluted mash is applied to the drums in a manner assuring good adherence, and dehydrated under those conditions of temperature and time which yield a product of good flavor and color and of the required dryness. The product is recovered from each drum of the drier as a thin, continuous sheet of controlled thickness. The sheets are broken to the desired size, screened to remove fine particles and packaged.

FACTORS CONTROLLING TEXTURE

Raw Material

Idaho Russet Burbanks are used commercially in making dehydrated mashed potatoes. High solids varieties have heretofore been necessary to obtain good texture on reconstitution. Low solids potatoes rarely make a mealy, non-sticky mash even when cooked and mashed fresh. In the flake process, however, since the introduction of the precooking step, several varieties of lower solids content, Katahdin, Kennebec and Russet Burbank grown in the East, have been used to make a product of excellent quality. The Katahdins for example, contained 20.4% solids, 1.7% sugar and 13.2% starch.

Cooking

Potatoes for flake production are sliced into 5/8" thick slabs which are washed before cooking to remove surface starch. The washed slices are placed on a perforated tray, to a depth of from one to three slices, and cooked in steam at atmospheric pressure. Work reported previously (1) has shown that an improvement in texture results when cooking time is reduced to a minimum. For example, when flakes were made from slices cooked 35, 20 and 12 minutes and then reconstituted, the texture of the reconstituted mash was best from the 12-minute cook, next best from the 20-minute cook, and worst from the 35-minute cook.

3. Mention of specific products in this paper is not to be construed as a recommendation or endorsement of them by the Department of Agriculture over similar products not mentioned.

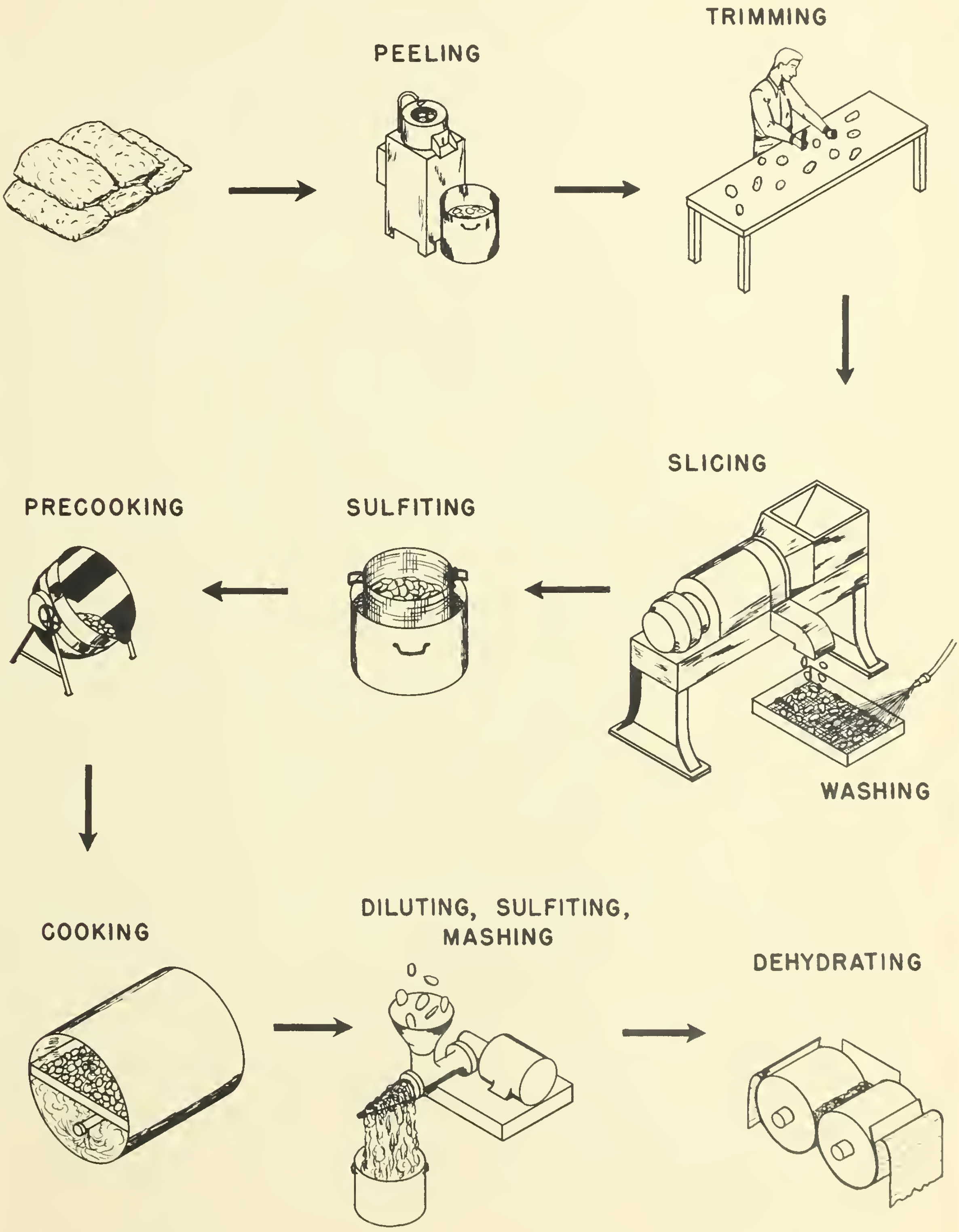

Figure 1. Potato Flake Pilot-Plant Flow Sheet

Further reduction of the cooking time at 212° F. (100° C.) could not be made since 10 minutes is required to bring the temperature of the center of the slices to 212° F. (100° C.) and the slices are barely cooked enough to mash after 12 minutes.

Precooking

Subsequent investigation, however, shows that other variations in the cooking technique have even greater effect on texture of the reconstituted product. It has been shown that, by the use of a two-stage cooking method, texture of the mashed potato reconstituted from potato flakes can be varied and controlled in the range from excessively grainy, through mealy to very creamy and smooth. The method evolved consists in a precook at a temperature high enough to gelatinize the starch but considerably below 212° F. (100° C.), followed by a final cook at 212° F. (100° C.) The raw potato slices are heated in water or steam, preferably at a temperature of 150 to 165° F. (65.5 to 73.8° C.) for 15 to 30 minutes. After this treatment, the slices are no longer crisp as when raw, but are tougher, resilient, somewhat translucent, and the starch in the cells is completely gelatinized. At this point in the process there is no difference in appearance between slices precooked at different temperatures in the range of 140 to 180° F. (60 to 82° C.). Reeve (3), in his investigations of conditions influencing texture of cooked potato tissue, observed that slices soaked 30 to 90 minutes at 167° F. (75° C.) or at 194° F. (90° C.), and then steamed or boiled, also showed no gross differences. The precooked slices are next cooked in 212° F. (100° C.) steam to the stage where they can be mashed without excessive cell damage. This operation requires about the same time as for raw slices, about 16 minutes. The mash is then diluted and dehydrated to produce potato flakes. These, when reconstituted, exhibit differences attributable to variations in the time and temperature of precooking. These differences range from undesirable graininess through desirable mealiness to a creamy texture. The effect of precook temperature on texture is shown in Table 1.

For the series of tests shown in Table 1, potatoes were selected which had not produced a satisfactory product before introduction of the precooking technique. These were Idaho Russets from fraction 3 as indicated in Table 2.

In the tests shown in Table 1, the potato slices were placed in water at the temperatures shown, and the temperature of the bath was maintained for 30 minutes. Slices for test 5 were not precooked. Final cooking was in steam at 212° F. (100° C.) for 16 minutes in all cases. Slices were then mashed, the mash diluted with water, and dehydrated on a double drum drier. Operating conditions, i.e., drum clearance, drum speed, and steam pressure in the drums, were the same for each test. The dehydrated potato flakes thus produced in each test were reconstituted and submitted to a panel for comparison of texture. Panel members were instructed to rate the samples for texture by arranging them in order from the most mealy to the least mealy. Members were asked also to indicate preference as to texture, but only after having arranged samples in the order of mealiness. In aligning the samples in the order of mealiness, the panel was unanimous. The product of test 5 was visibly different from the other four products. It was pasty and had a starchy surface glaze. Differences between products of tests 1 to 4 were not easily detectable by eye, but readily detectable by the tongue when tasted. The difference between these samples can be described as a difference in size of the particles making up the mash. Sample 1 felt "sandy" to the tongue, while samples 2, 3 and 4 had the mealiness characterizing a baked Idaho potato.

TABLE 1

Effect of precooking temperature on texture

Test No.	Precook, 30 Min. °F.	Final cook 212° F. Min.	Texture of reconstituted mash
1	140	16	Poor texture because of large particle size (grainy)
2	155	16	Smaller particle size, mealy, good texture
3	165	16	Particle size smaller than 2, mealy, excellent texture
4	180	16	Less mealy, fair texture
5	None	16	Not mealy, pasty

TABLE 2

Description of potatoes for precooking tests

Fraction	1	2	3	4
	Sp. gr higher than 1.090	Sp. gr. 1.085 to 1.090	Sp. gr 1.075 to 1.085	Sp. gr. lower than 1.075
% of total batch in fraction	8.3	35.7	47.2	8.8
Total solids, %	24.8	24.3	22.3	20.8
Starch, %	18.24	16.95	16.04	14.10
Sugars, %	0.91	0.75	0.70	0.66

Similar tests were made to determine the effect of precooking time on texture An example of this effect is shown in Table 3 Table 3 illustrates the principle that has been observed in precooking at each of the temperatures investigated in the range from 140 to 180° F. (60 to 82° C.). Particle size of the reconstituted product increases as the time of precooking is increased. The optimum time, i.e., the time required to obtain a desired texture varies with the precook temperature and with the potato variety used. For the potatoes used in tests 1 to 8 of Tables 1 and 3, precooking at 155 to 165° F (68 to 74° C.) for 30 minutes yielded the best product For Katahdins, Kennebecs and Russet Burbanks grown in the East, precooking at about 150° F. (65° C.) was best.

In any procedure where water or steam is used for cooking, some loss of solubles inevitably occurs When steam is used to cook potatoes for mashing as is generally done industrially, losses are less than when boiling water is used as in the home kitchen. Preliminary tests indicate that potato slices 5/8" thick precooked in twice their weight of water at 160° F. (71° C.) for 30 minutes and then finally cooked in steam lose about 2-1/2 to 3% of their total solids content. Tests on slices from the same potatoes cooked by boiling in an amount of water equal to the weight of slices, indicate also a loss of about 2-1/2 to 3% Loss of nitrogen compounds is about the same in each case loss of sugar in boiling appears to be about twice that in precooking.

Water precooking was used in the pilot plant for reasons of easier temperature control If losses appear to be an important economic factor in commercial plant design, the amount of water used can be reduced, or steam precooking can be substituted since texture improvement and control can be had with steam as well as with water in pre-cooking.

Loss of flavor due to loss of solubles in the water precooking method becomes noticeable when precooking time is extended beyond about 30 minutes. Samples prepared by water precooking for 30 minutes or less have excellent flavor.

While an understanding of the effects of variations in the precooking step on product texture has been gained in these recent investigations, further work is required to explain them in terms of changes in the potato tissue Studies as to the nature of these changes are in progress Probably the two most important histological changes occurring during precooking are the weakening of the cementing material between the potato cells and the gelatinization of the starch within them. Personius and Sharp (2) determined, by measurement of tensile strength of cooked potato tissue, that within the temperature range of 113 to 167° F. (45 to 75° C.) weakening of the cementing material is carried to a definite point at each temperature and then stops, and that at 167° F. (75° C.) tensile strength is comparable to that of fully cooked potato They noted no difference between soggy and mealy potatoes in the adhesion of cells and concluded that cell separation is not dependent upon starch gelatinization. It was pointed out by Whittenberger and Nutting (5) that the mechanics of cell separation (sloughing) during cooking probably is associated with the swelling capacity of starch during gelatinization, which develops pressure within the cells sufficient to fracture the intercellular cement. Reeve's comprehensive study of conditions influencing texture in potatoes (4) indicates that the properties of gelled starch in potato tissue are related to texture of potatoes, that the influence of these properties can be modified by heat treatment and by other conditions, and that no single factor alone may be the cause of textural quality

TABLE 3

Effect of precooking time on texture
[Temperature of precook: 155° F. (68.2° C.)]

Test No.	Precooking Time, min.	Texture of Reconstituted Flakes
6	15	Mealy, small particle size, good texture
7	30	Mealy, larger particle size, good texture
8	60	Poor texture because of large particle size (grainy)

The processing studies reported here suggest that the differences in the properties of the starch occurring as a result of different precooking conditions contribute more to texture control of the reconstituted potato flake than do the differences in ease of cell separation If complete weakening of intercellular cement is accomplished at 167° F (75° C), as reported by Personius and Sharp (2) to the same extent as in fully cooked tissue, then samples 3 and 5 of Table 1 would be expected to have similar texture, provided cell separation were the only factor contributing to texture. Sample 5, however, was considerably worse than sample 3 Moreover, all samples of potato flake prepared by the precooking technique tolerate more reconstituting liquid than those prepared without precooking Flakes prepared without precooking normally require 4-1/2 parts of liquid to one part of flakes for reconstitution. Flakes prepared by precooking require 5 parts of liquid to one part of flakes to give the same apparent consistency of reconstituted mash. This greater moisture retention capacity is indicative of changes in the cell content, probably in the physical properties of the gelled starch. It is also of commercial advantage since it permits more servings per unit weight of potato.

Dilution of Mash

Flake Density and Strength: In previously published work on potato flakes (1) it was shown that dilution of high solids content mashed potato, within limits, resulted in certain desirable properties of the drum dried flakes. Among these are higher flake density, i.e., more cells and less voids per unit area, and a greater resistance of the flake to shattering during breaking to desired size. Both density and strength increase as high solids mash is diluted, reaching a maximum when solids content has been reduced to about 20%, and diminishing on further dilution.

Flake Dryness Another important result achieved through controlled dilution of the mashed potato prior to dehydration is the production of potato flakes of lower moisture content. Because of its better adherence to the drier drums, and consequent better drying efficiency, mash prepared from potatoes of high solids content when diluted to about 20% solids yields a flake of lower moisture content than the same mash dried undiluted at the same drying conditions Qualitative observations on the rate of rehydration of potato flakes indicate that flakes of lower moisture content rehydrate less rapidly than flakes of higher moisture content made from the same potatoes using the same processing procedure Flakes of lower moisture content produce a mash of more mealy, less pasty texture when reconstituted This improvement is believed to result from a decrease in cell rupture brought about by the slower but still quite rapid, rehydration of the flakes of lower moisture content An example of the effect of flake dryness on texture of reconstituted mash is shown in the following

Flakes were removed from the drum drier at 7.35% moisture content and were further dried to 2% in an oven Flakes made from the same mash were taken from the drum drier at 3.2% moisture content, and were allowed to pick up moisture in a humid atmosphere until they contained 12.1% moisture The four flake samples were reconstituted and compared by a taste panel for texture. The amounts of reconstituting liquid were adjusted for each sample, based on its moisture content, to give the same solids content in the reconstituted mash. The panel arranged the samples in the order -- most mealy, 2% moisture; next and equal to each other, 3.2% and 7.35% moisture; and least, 12.1% moisture

Flake Thickness. A critical factor in avoiding cell rupture during manufacture of flakes is the clearance between the drums of the drier. If the clearance is too small, the individual potato cells are crushed, and the flake produced reconstitutes to a pasty product. If the clearance is too large, the cells adhere to the drums in agglomerates. This condition results in a product of higher moisture content, since it makes removal of water more difficult. It may also result in a lumpy product, since on reconstitution large agglomerates may not rehydrate completely. In practice, a flake thickness of 0.005" to 0.009", produced with a drum clearance of about 0.007" to 0.010", is preferred. Flake thickness has been more fully discussed in an earlier publication (1).

Flake Size. The product of the drum drier is removed from each drum as a thin continuous sheet the full width of the drum. These sheets must be broken into flakes of a convenient size for packaging. When they are broken, cleavage occurs not only between the cells, but through them as well, thus some free starch is released at the periphery of the flake. If the flake is large, the broken peripheral cells are insignificant in number compared to the number of whole, undamaged cells contained in the flake. As the pieces become smaller, the ratio of the number of peripheral cells to the number of enclosed cells increases, and a size is eventually reached where a difference in texture can be detected. Dilution of the mashed potato before drying permits the production of a flake of higher density, i.e., having more cells per unit area. A high-density flake suffers less damage on breaking than one of low density. Mathematically, if the number of cells per unit area of flake is doubled, the periphery increases only as the square root of two. It follows, therefore, that a flake of high density will have relatively less free starch released during breaking than one of low density.

Many samples of potato flakes have been prepared and distributed to demonstrate the product. These have been made up of flakes ranging in size from 3/16" to 5/8", having a package density of about 7 pounds per cubic foot.

It may be desirable, however, for military use and for economy in packaging to reduce the flake size and increase bulk density. The minimum size permissible will have to be determined on the basis of preference tests using taste panels large enough to give significant results. A small taste panel can, however, determine the point in size where a detectable amount of pastiness occurs. For example, a panel could not detect pastiness in, or distinguish between, mashed potato reconstituted from flakes of the following sizes: through 2 on 4-mesh; through 4 on 6-mesh, through 6 on 10-mesh. The panel could detect pastiness, however, in mash made from flakes passing 10-mesh and retained on 20-mesh. It appears, therefore, that flakes can be made as small as 10-mesh without noticeable increase in pastiness on reconstitution. Flakes of this size have a bulk density of about 10.5 pounds per cubic foot. The largest package consistent with reasonable packaging cost is desirable for "sales appeal".

CONCLUSIONS

The texture of mashed potato reconstituted from potato flakes is influenced by many factors. Among these are the condition of the potato tissue as affected by precooking and final cooking, flake thickness, density, moisture content and size.

To obtain good texture heretofore from the flake process, as in other processes, potatoes of high solids and low sugar content have been required. It is now possible using the precooking technique, to make flakes of excellent quality from potatoes previously considered unsatisfactory for dehydration as mashed potato. With each of the four potato varieties tried, control of mealiness of the reconstituted product has been obtained by adjustment of the temperature and time of precooking. Flakes made by precooking permit the use of larger volumes of reconstituting liquid, yielding more reconstituted mashed potato per unit weight of dry flake.

Flakes of lower moisture content yield reconstituted mashed potato of better texture than those of higher moisture content. Dilution of mash before dehydration facilitates obtaining a product of low moisture content by allowing better adherence to the drums which permits better drying efficiency.

Flake size influences texture of the reconstituted mash. Broken cells on the periphery of the flake contribute free starch, which in large enough quantity would make the product pasty. The ratio of the number of broken cells to the number left intact, increases as flake size is reduced. It has been shown, however, that flakes passing 6-mesh and retained on 10-mesh have excellent texture, not significantly different from flakes in the size range 3/16" to 5/8". It is indicated that flakes of higher density (more cells per unit area) suffer less damage than flakes of lower density. High density is obtained by dilution of the mash before dehydration. Flake thickness, controlled by clearance between the drier drums, also influences texture. If clearance is too small, starch is released from the cells, and flakes so produced are pasty when reconstituted. Too large a clearance yields a flake with cell agglomerates which are difficult to dry and which may result in a lumpy reconstituted mash. Optimum thickness for flakes made on a double drum drier is 0.007 to 0.009".

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